

DAN passive data analysis to estimate radiation environment at the surface of Mars

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Outline

- Introduction
 - DAN instrument description
 - Background radiation environment
 - Objectives and task description
- Methodologies
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Introduction (1/3)

MSL mission and DAN instrument

- The Mars Science Laboratory (MSL, a.k.a. Curiosity Rover) is a robotic planetary exploration rover currently on the surface of Mars.
- The Dynamic Albedo Neutron (DAN) instrument is on board MSL. The objectives of DAN are:
 1. Measure the subsurface bulk hydrogen abundance (in the form of water or hydrated minerals)
 2. Measure the neutron background environment on Mars' surface.



Introduction (1/3)

MSL mission and DAN instrument

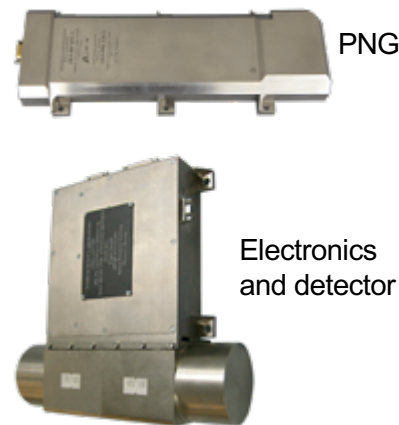
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Introduction (2/3)

DAN description

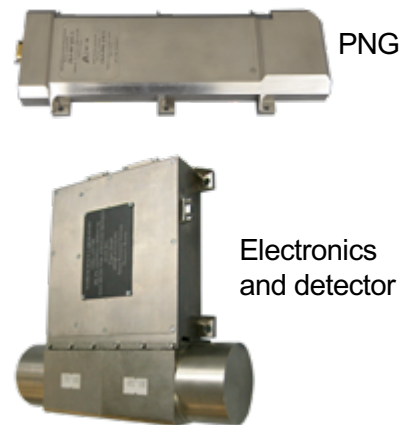
- DAN measures thermal ($E < 0.4$ eV) and epithermal neutrons (0.4 eV $< E < \sim 1$ keV)
- It operates in two different modes: active and passive.
 - The active mode uses a pulsed neutron generator (PNG) to study the geological characteristics of the subsurface.
 - In the passive mode, DAN measures the background neutron environment from Galactic Cosmic Ray (GCR) interactions and MultiMission Radioisotope Thermal Generator (MMRTG)



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Objective and task description

- Isolate the GCR contribution from the DAN thermal counts in passive mode.
 - Remove possible dependences of the DAN passive data on soil composition and geological features.
- Extend the usability of the DAN passive measurements.
 - Understand of short/long term variability of the low energy neutron environment at the Mars surface.

Conditions that affect DAN measurements

Water Equivalent Hydrogen and Absorption Equivalent Chlorine

In passive mode, the thermal counts can be affected by interactions with the regolith composition from:

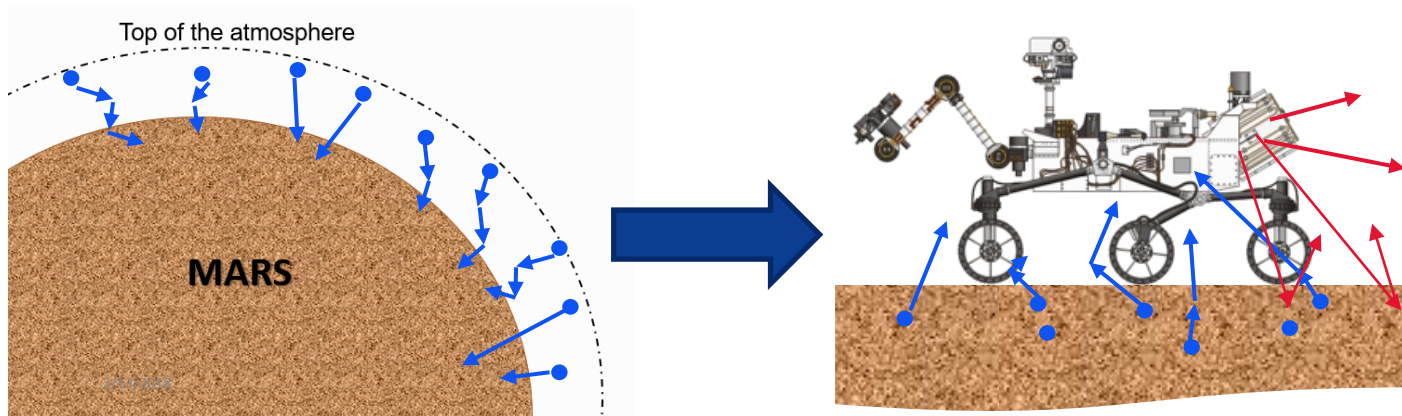
- Scattering interactions – scatterings of the neutrons with moderating nuclei, particularly hydrogen atoms (thermalization)
 - **Water Equivalent Hydrogen (WEH)** accounts for the combined effects of the moderation of neutrons with various soil elements
- Thermal neutron absorption interactions - elements like Cl, Fe, etc. with high neutron absorption cross-sections will capture thermalized neutrons
 - **Absorption Equivalent Chlorine (AEC)** accounts for the combined effects of neutron absorption elements in the soil composition

Radiation environment and planetary interactions (1/2)

- GCR are energetic protons and ions able to interact with an “entire planet”
 - Atmospheric interactions : The GCRs traverse the atmosphere and interact with the nuclei in the atmosphere. The atmosphere slows down the GCRs and the secondary particles can be created
 - The atmospheric column density can be important when computing the variations in DAN’s thermal counts.
 - Surface and subsurface interactions: Particles that reach the surface will interact with the nuclei in the regolith. They generate secondary particles until they get absorbed or leak back to the atmosphere.
- MMRTG neutrons are from the spontaneous fission of plutonium isotopes and (α ,n) reactions with low-Z materials present in the fuel.

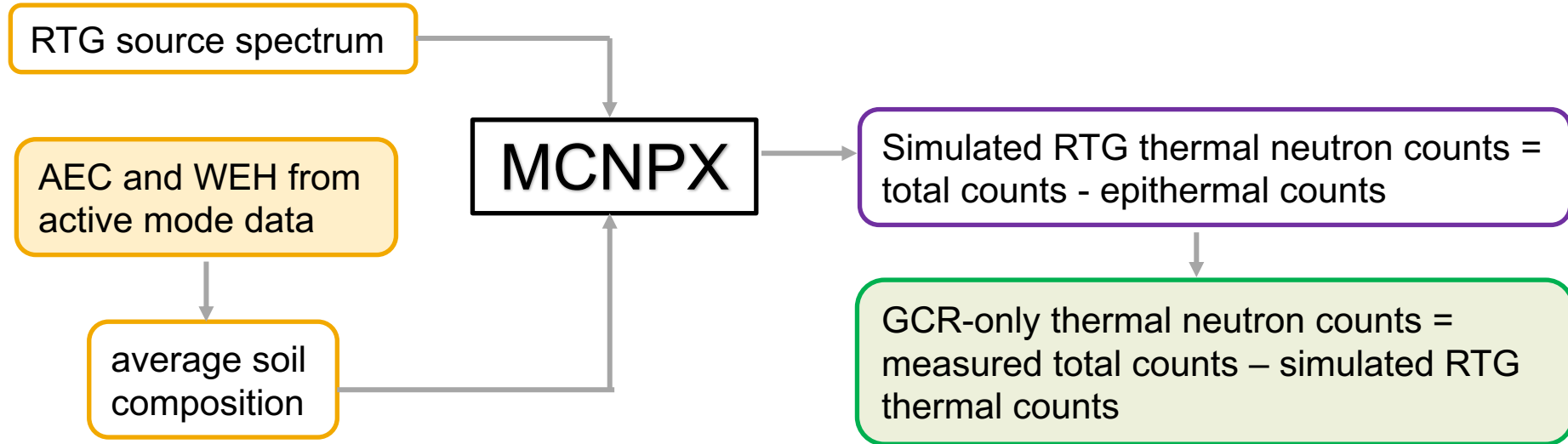
Radiation environment and planetary interactions (2/2)

In the passive mode, the main sources of background radiation are GCR and MMRTG neutrons.



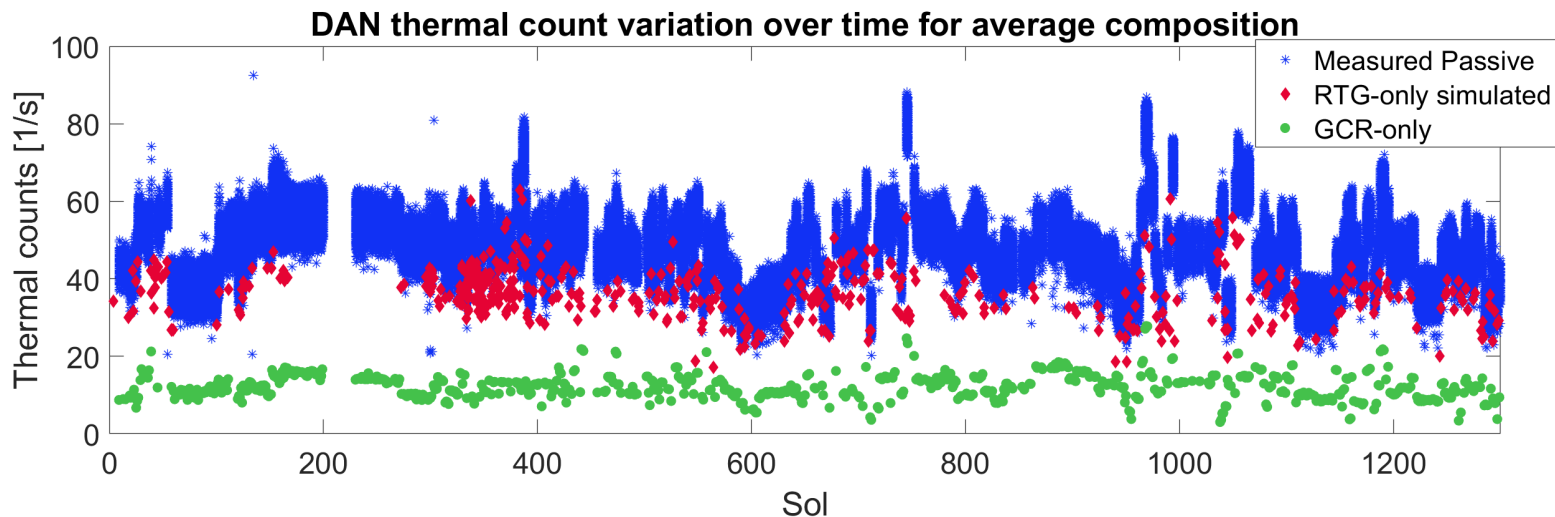
Description of simulations and data reduction

Monte Carlo transport simulations were done to estimate the RTG contribution and thus obtain the GCR-only thermal neutron counts at a particular location (*i.e.*, particular composition)



Methodology

$$\boxed{\text{Passive thermal counts (known - measured)}} = \boxed{\text{RTG-only thermal count contribution (known-simulated)}} + \boxed{\text{GCR-only contribution (unknown-goal)}}$$

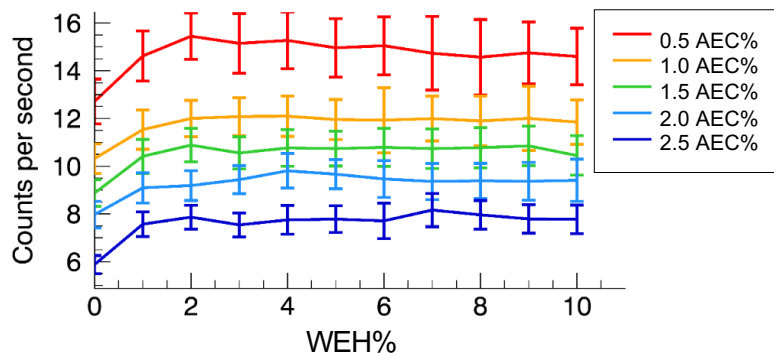


GCR Thermal counts dependence

Simulations for fixed environmental conditions* on Mars

A previous work has shown dependence of the DAN thermal neutron counts on WEH% and AEC% for the simulated GCR contribution.

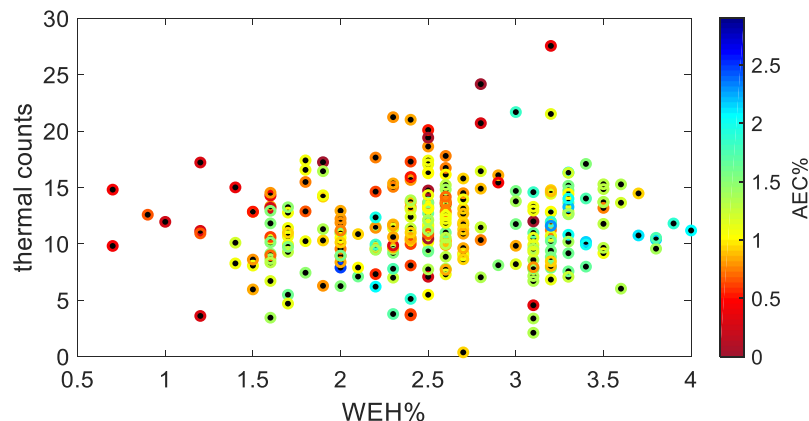
*Fixed atmospheric conditions, GCR intensity, regolith density, etc.



Estimated GCR-only count

No obvious trend is observed when the GCR-only thermal counts were averaged at a given location after RTG contribution was removed.

It appears we were able to decouple the WEH and AEC dependence for the GCR-only thermal counts.



GCR environment on the surface of Mars

- To better understand the relationship of the GCR-only DAN data, we used the RAD instrument data to compare the trend during the same periods of time.
- The RAD data set we used* is sol averaged (one value per day). Thus the DAN GCR-only data were prepared to the same time scale for direct comparison.

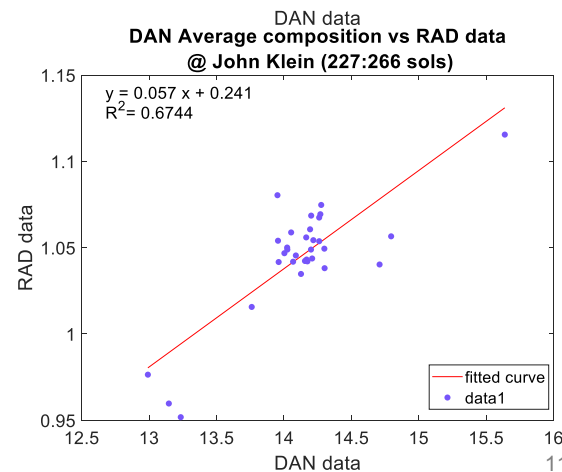
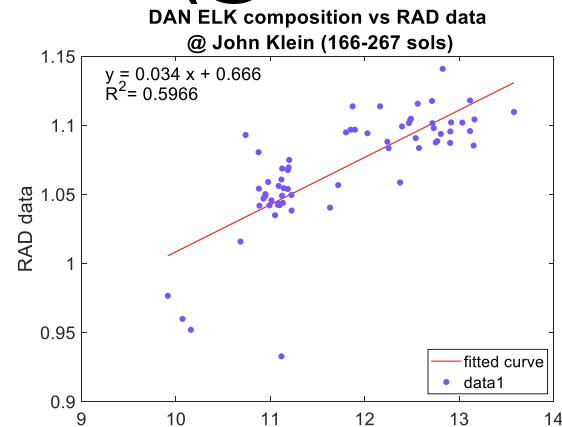
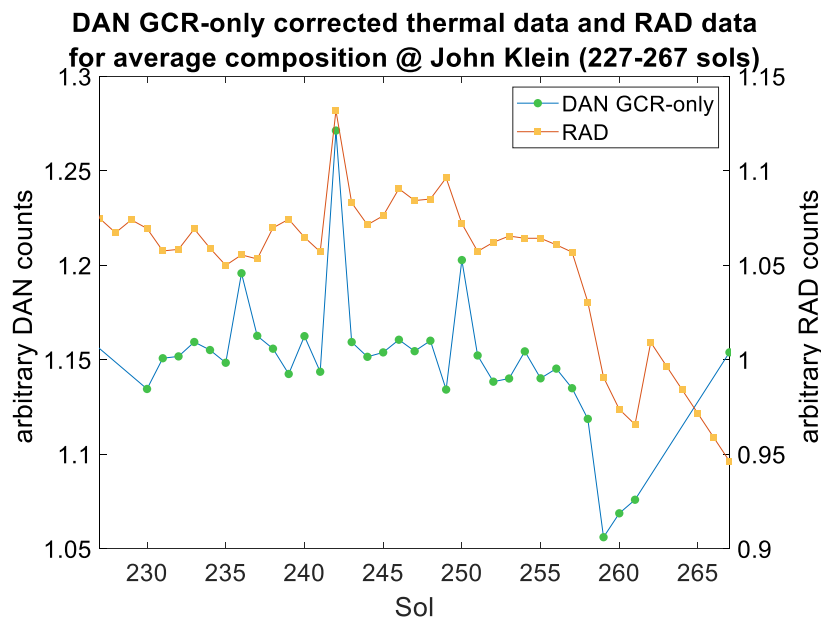
The mean values of the DAN counts for each sol, where RAD data were available, were then normalized to the total mission average of the DAN data:

$$counts = \frac{\overline{DAN(sol)}}{\overline{DAN(mission)}}$$

*From Chris Tate

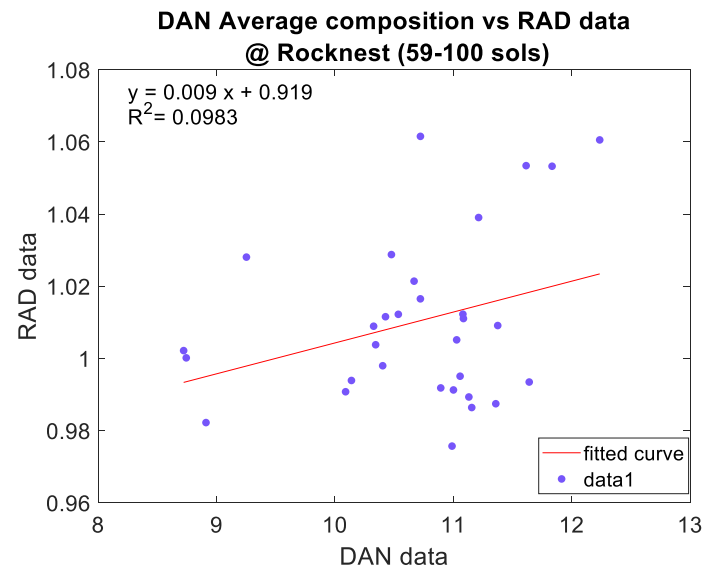
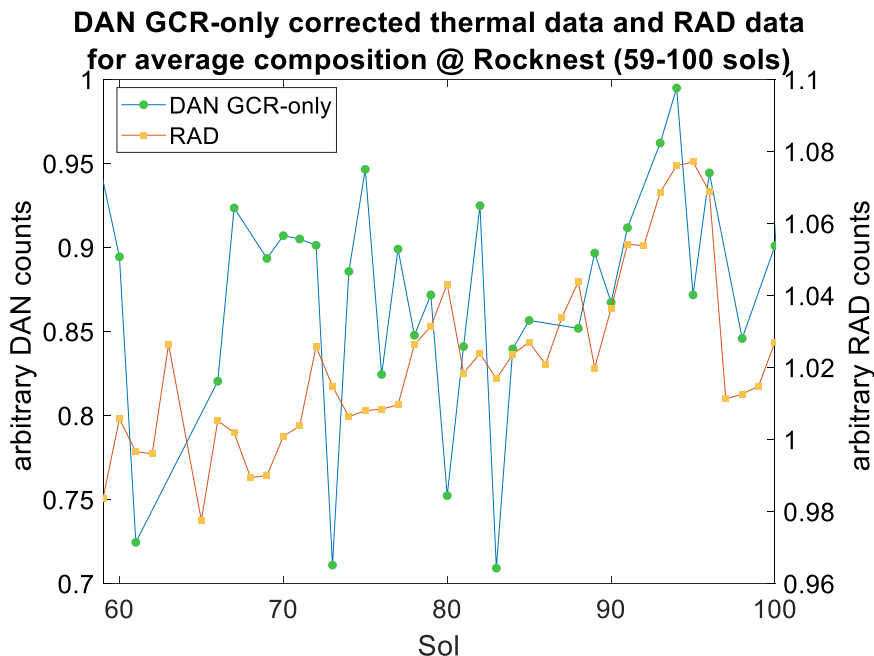
RAD and DAN one-to-one comparisons (@ John Klein)

For a given location (~100 sols), we compared DAN and RAD data



RAD and DAN one-to-one comparison (@ Rocknest)

For a given location at Rocknest (~40 sols), we compared DAN and RAD data



Discussion

- To date, we have found no clear correlation for the estimated GRC-only thermal counts with the AEC% and WEH% content.
- Comparison between the GCR-only DAN and RAD show similar trends at given locations.

Future Work

- Simulate DAN GCR-only thermal counts for different atmospheric conditions
- Analyze epithermal data using the same methodology
- Compare with other RAD channels
 - Use different RAD data than used in this study (PDS)
 - Determine how to use the RAD data to better anchor the GCR-only DAN data
- Compare with REMS data (atmospheric pressure, water vapor%, etc.)
- Investigate local variations including diurnal changes.
- Carry out an error propagation analysis
- Convert the counts to a physical unit (*e.g.*, flux)



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